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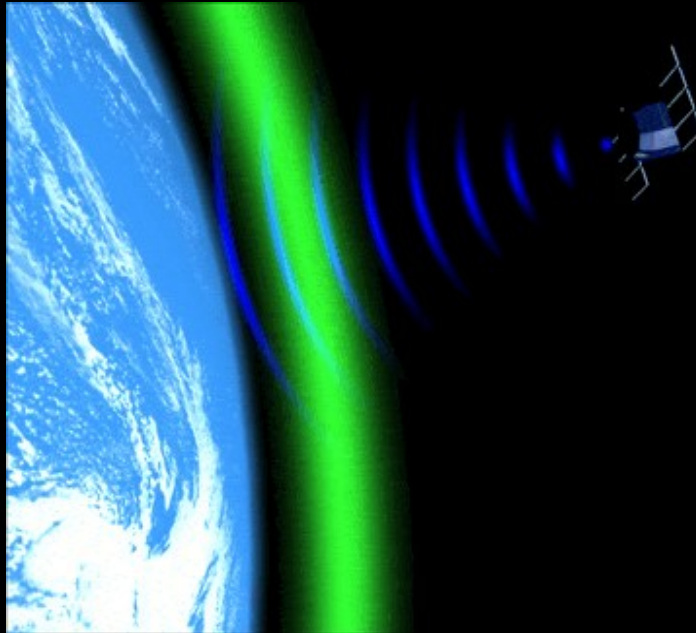
Mitigation of delay and scintillation effects using MIDAS

Damien Allain & Cathryn Mitchell
Invert Centre



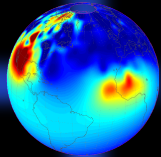
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<http://people.bath.ac.uk/da224/>

The Ionosphere



The ionosphere causes equal delay on the GPS code and advance on the carrier phase, proportional to:

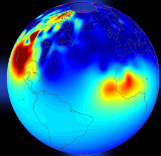
- the inverse of the square of the frequency
- the Total Electron Content along the ray path



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Outline



The ionosphere delays GPS signals

- When not properly compensated this delay is the cause of most of the positioning error
- This delay can be compensated by
 - **direct measurement** with a dual-frequency receiver
 - a **model** of the ionosphere, for example Klobuchar or IRI
 - a **real-time map** of the ionospheric delay

Comparisons between these methods over Europe are made for the last solar maximum.

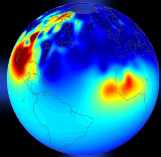
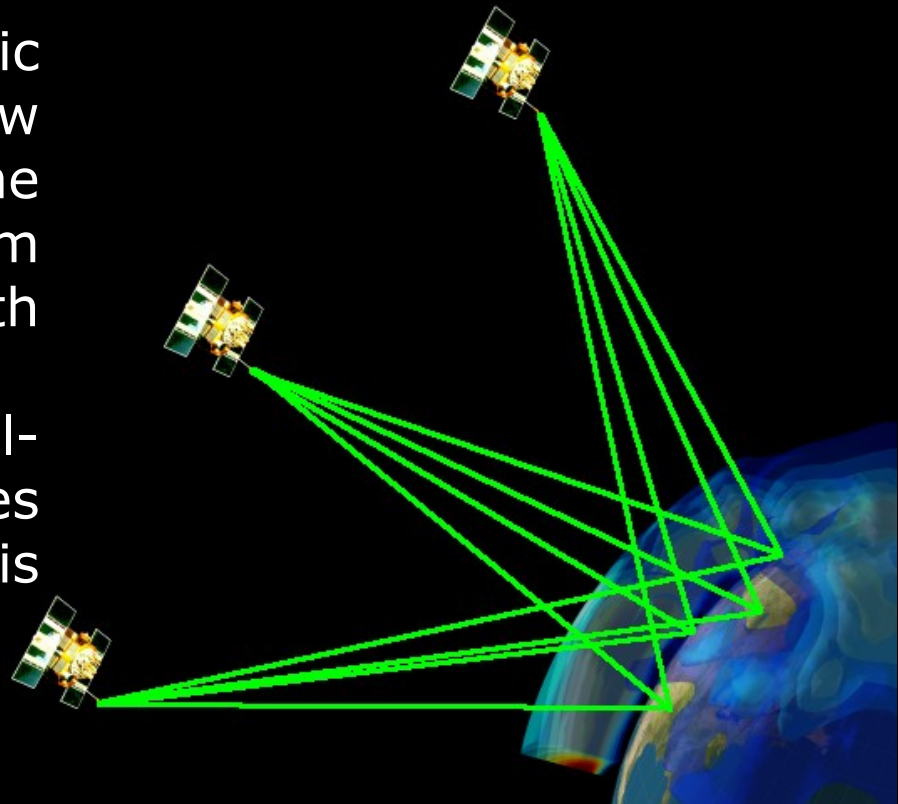
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4D Tomography

MIDAS (Multi Instrument Data Analysis System):

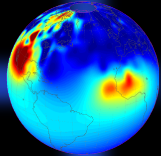
- downloads RINEX data from dual frequency receivers
- with a tomography from the phase advances on L1 and L2, gives a 4D image of the electron density in the ionosphere
- **Real-time**: The tomographic inversion takes a few minutes. A near-real-time (10 min prediction) system would be achievable with constant data streaming.
- **Predicted**: The near-real-time imaging requires 40 min prediction. This is limited by data latency.



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Pseudo-range



The P observable is the sum of :

- the true range r
- the receiver clock error $c\Delta_r t$ (specific and relativistic)
- the satellite clock error $c\Delta_s t$, from the ephemeris
- when working in the ECEF frame, the Sagnac distance r_s
- the ionospheric code delay or phase advance I
- the tropospheric delay T , calculated from a model
- noise, multipaths and negligible relativistic terms ε

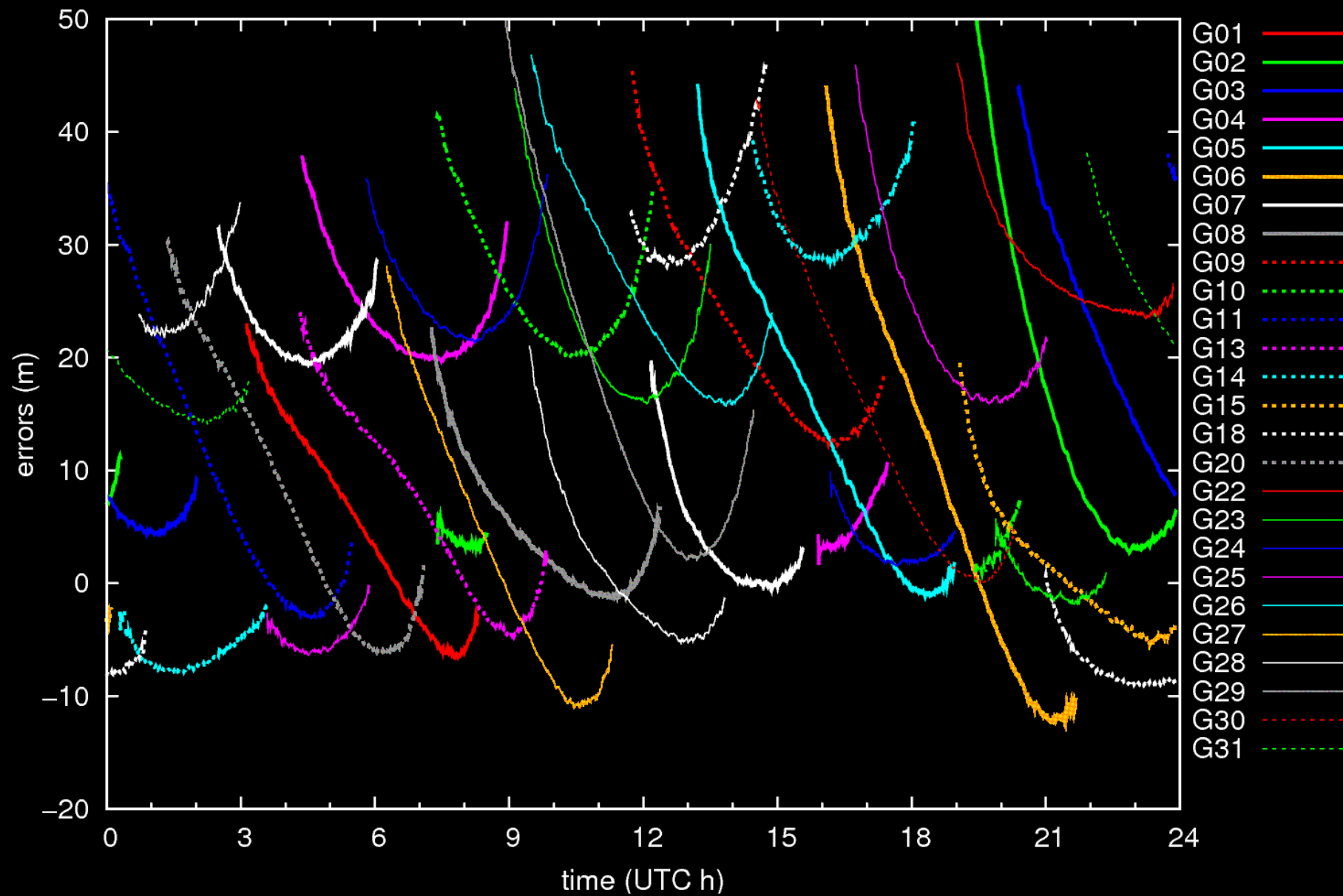
$$P = r + c\Delta_r t + c\Delta_s t + r_s + I + T + \varepsilon$$

Acknowledgements : IGS ephemeris

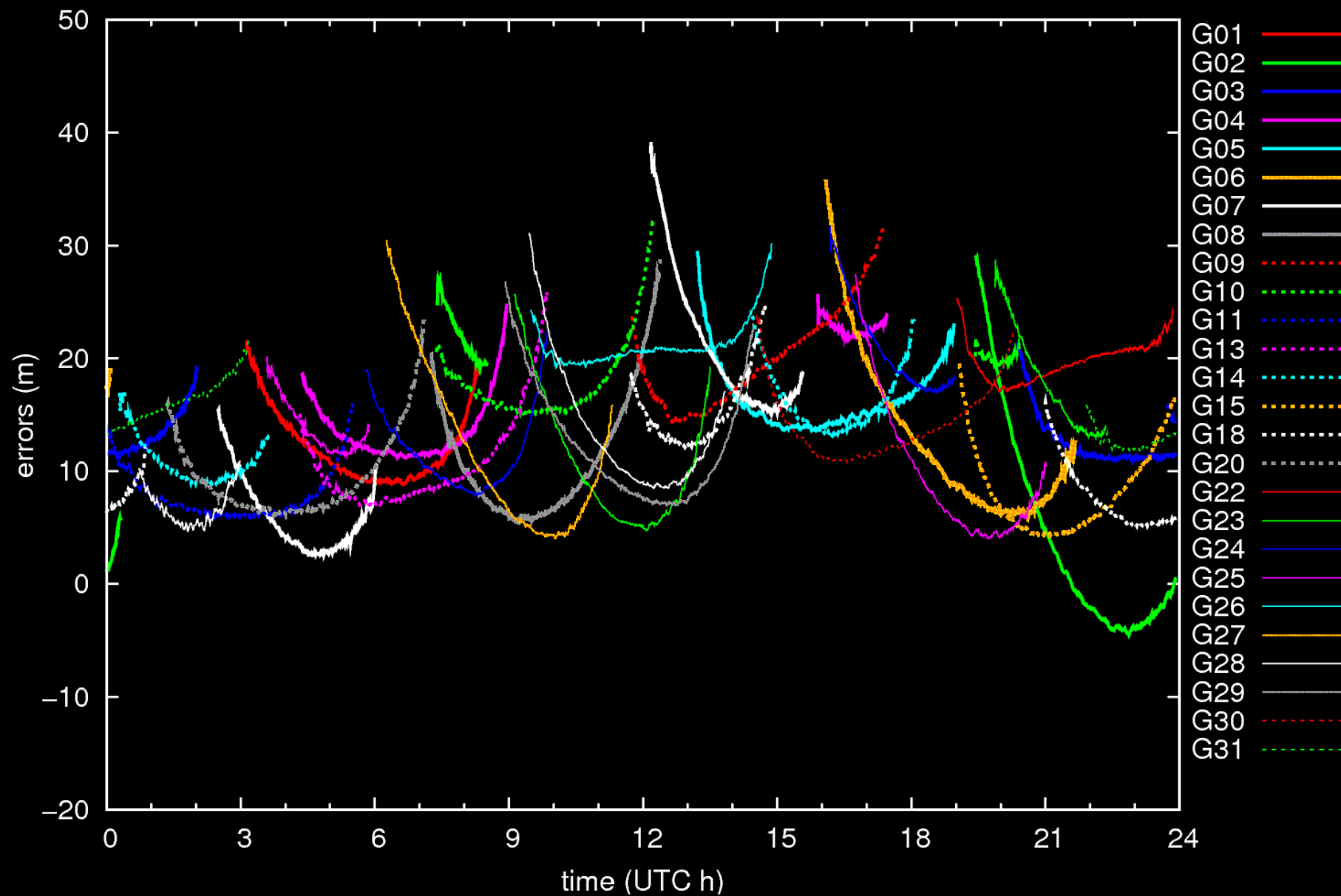
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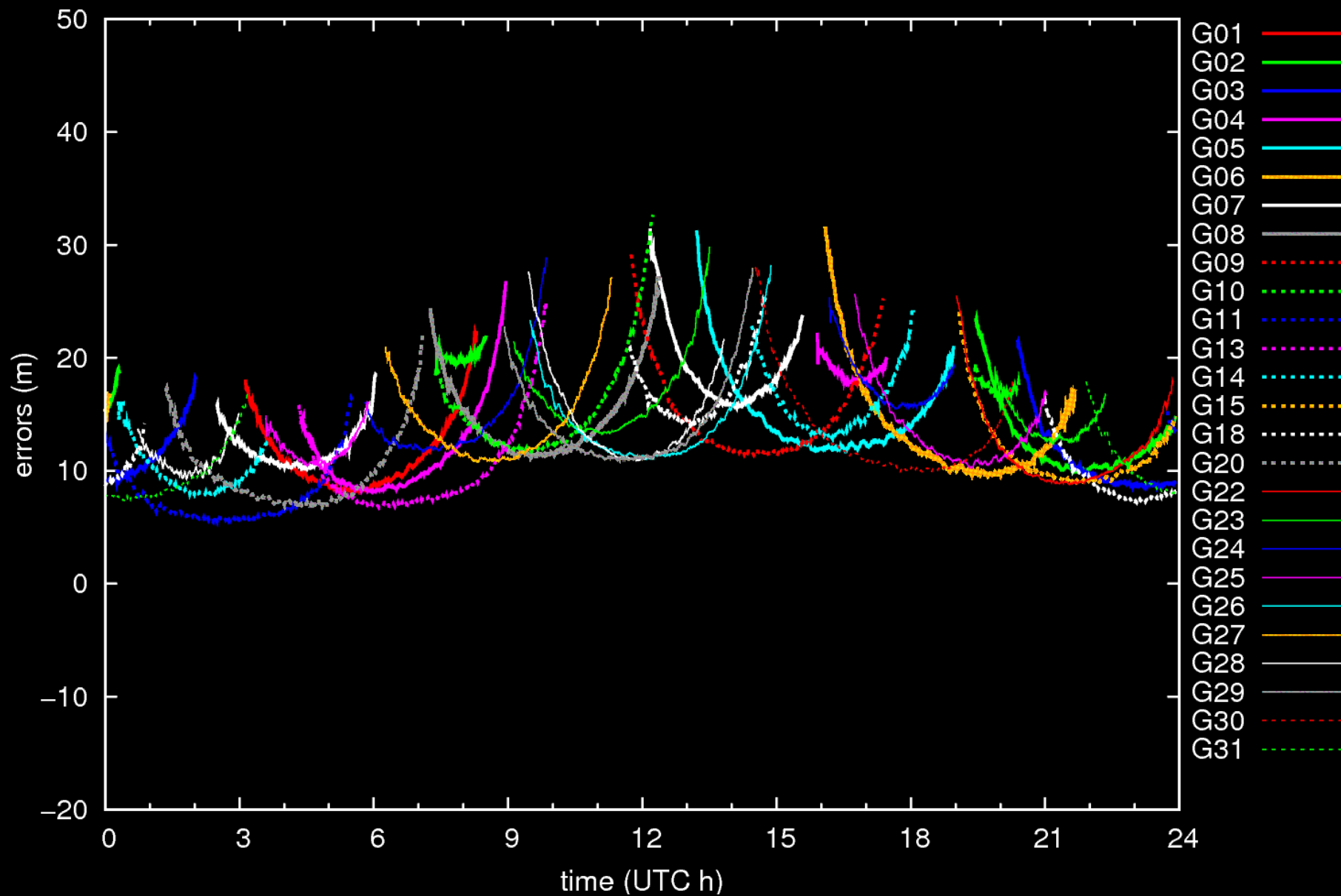
P1, without specific clock biases, ...



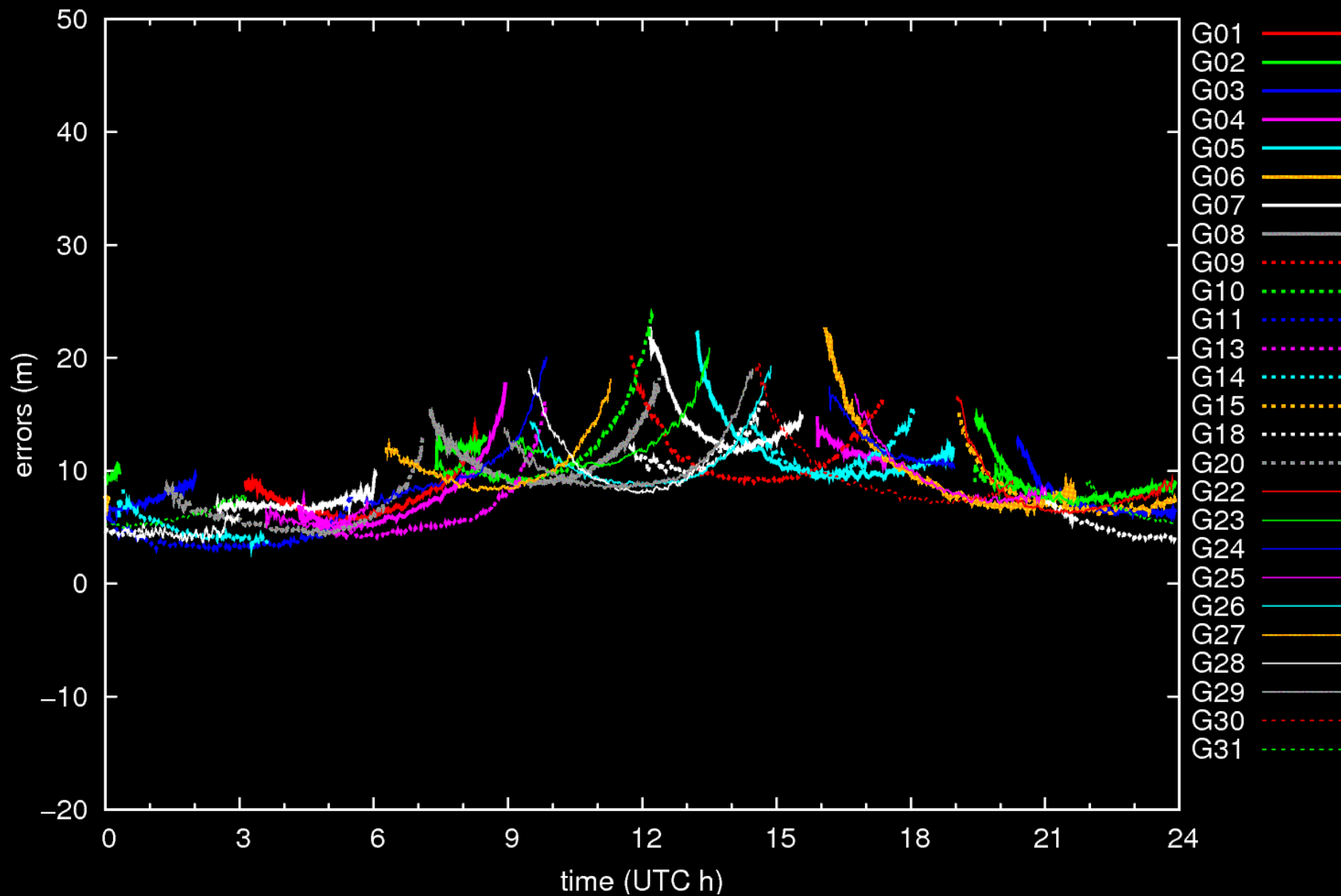
... removing Sagnac, ...



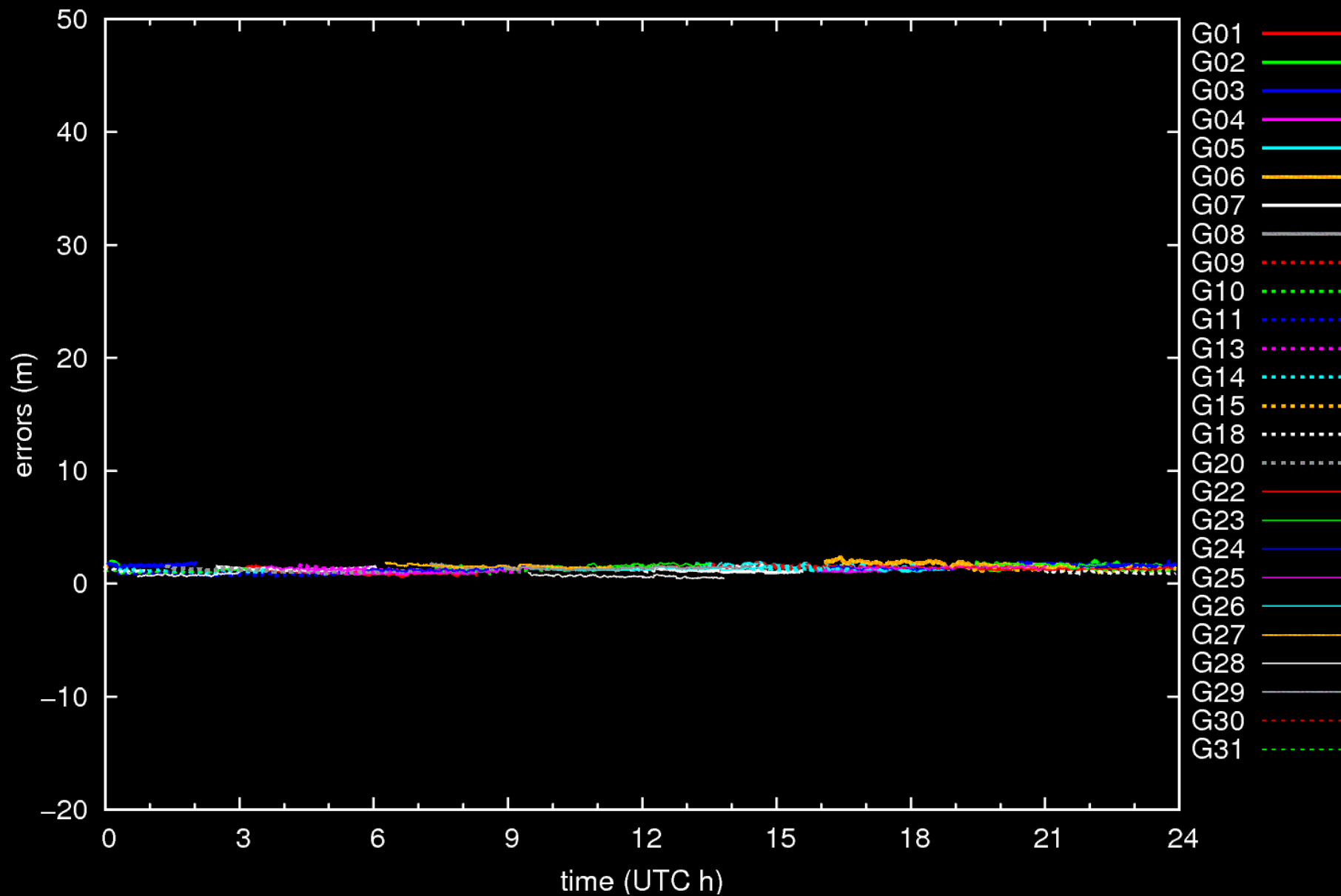
... removing satellite relativistic clock biases, ...



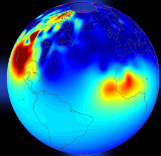
... removing tropospheric, ...



... removing ionospheric and phase filtering.



Data



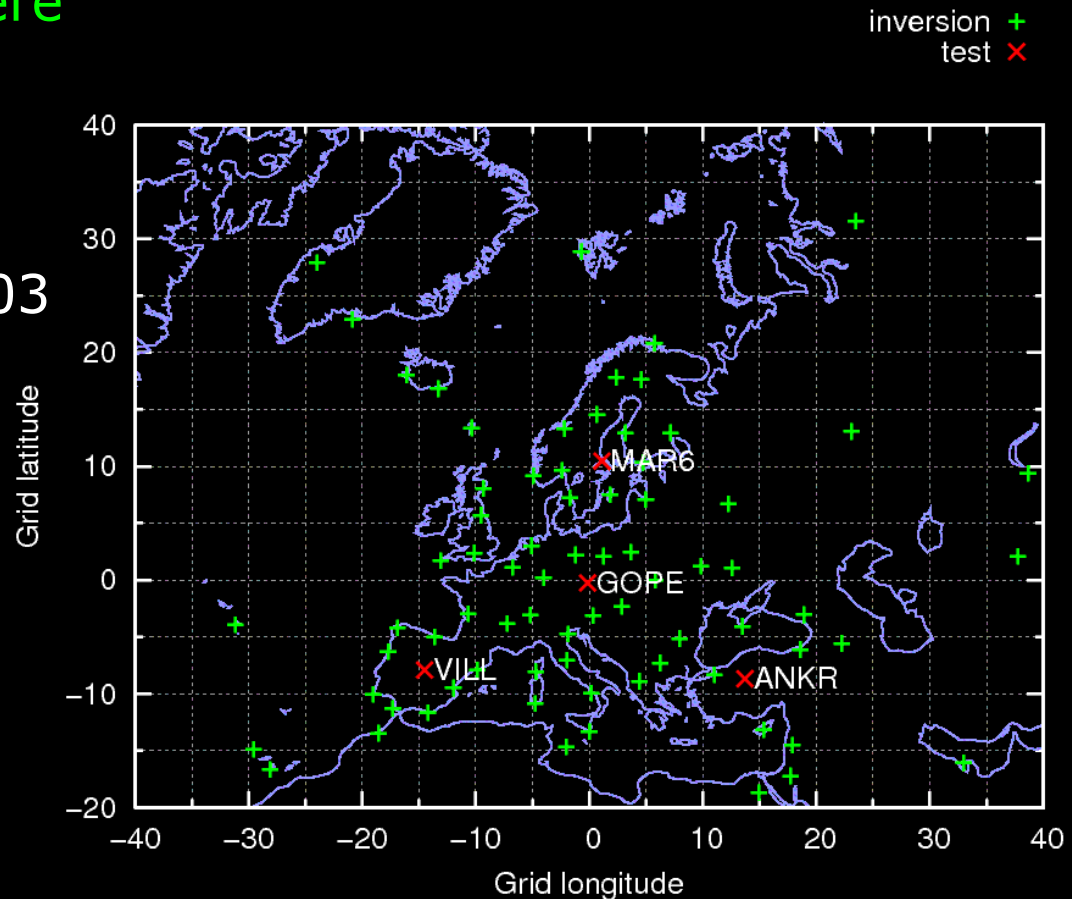
A set of dual frequency receivers is chosen:

- 4 receivers are taken as test receivers
- the others are used to create the image of the ionosphere

The study covers
all 2002 and
21 Oct to 4 Nov 2003

Acknowledgements :

- IGS and EUREF receiver data
- NGDC coastline data



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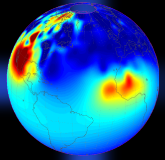


Methods

5 single frequency positions :

- no correction
- Klobuchar model
- IRI 2001 model
- MIDAS predicted
- MIDAS near-real-time

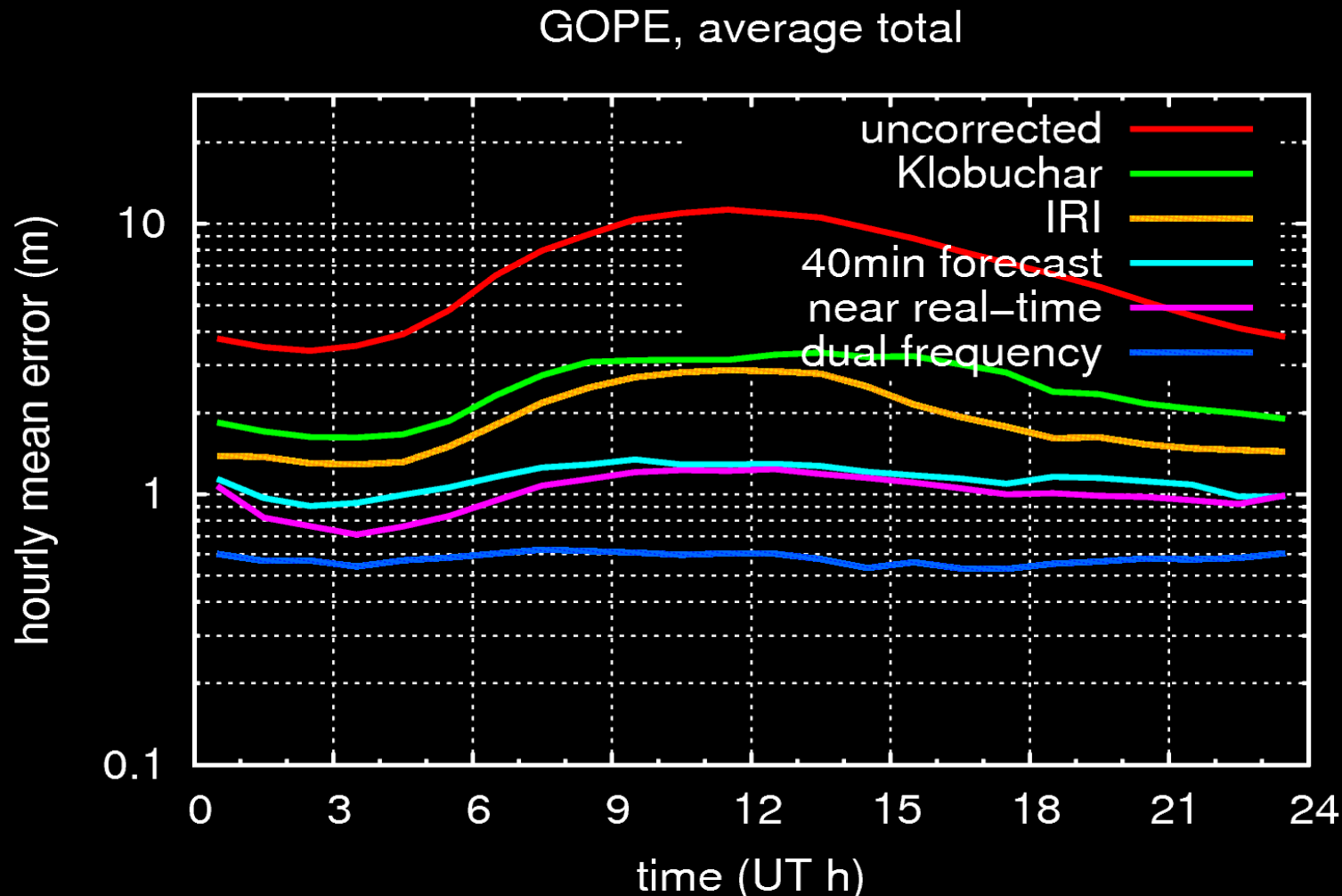
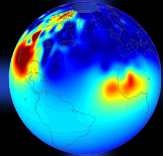
are compared to the dual-frequency (with phase-filtering using P1, P2, L1 and L2 observables) benchmark.



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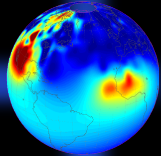
Results : average



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Results



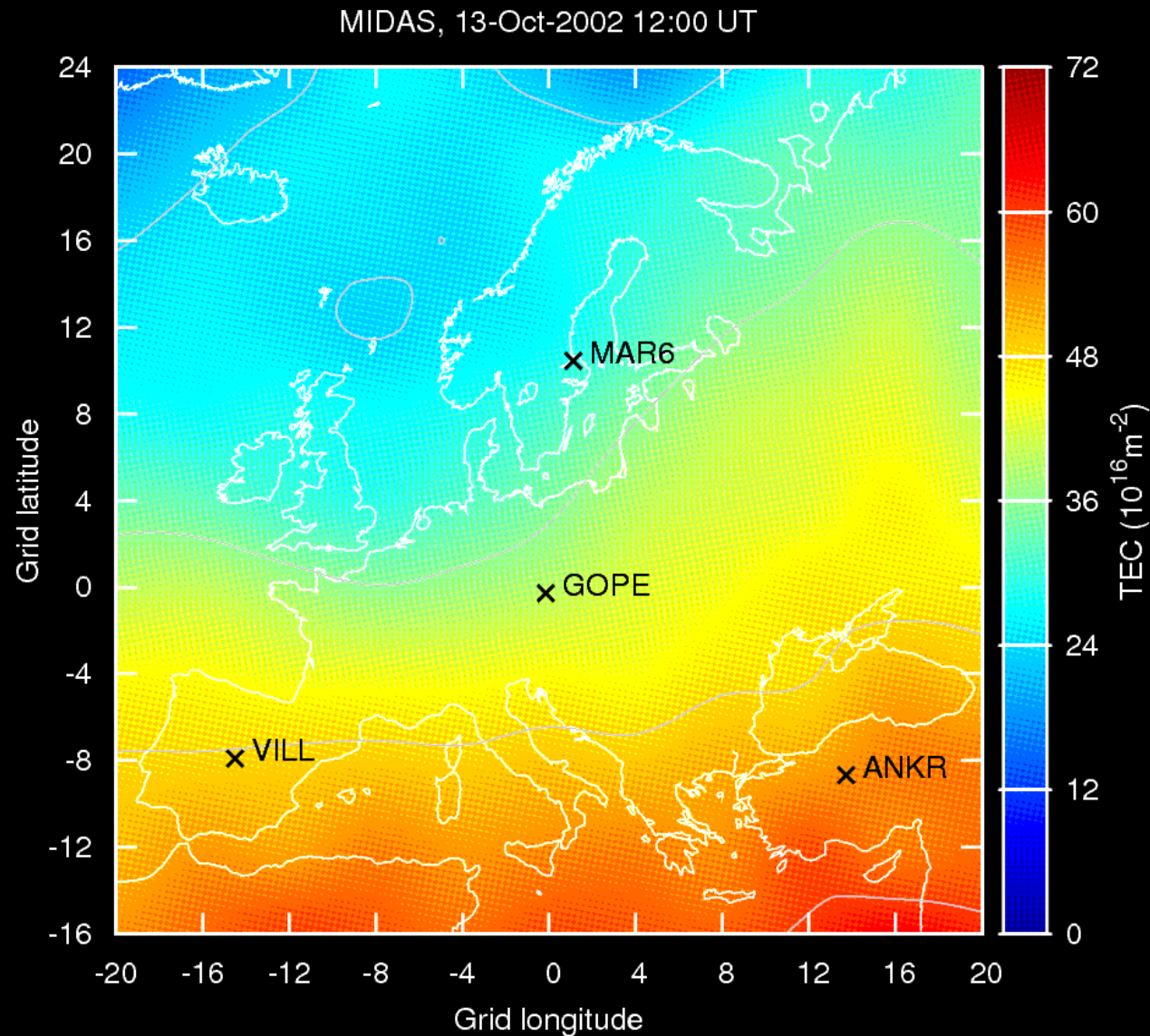
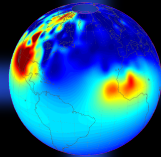
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The differences between
MIDAS near-real-time and
the **dual-frequency benchmark**
are due to :

- **space and time sparsity**
of the data
- **lack of phase filtering**



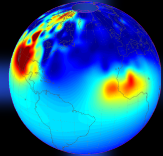
Results : quiet day



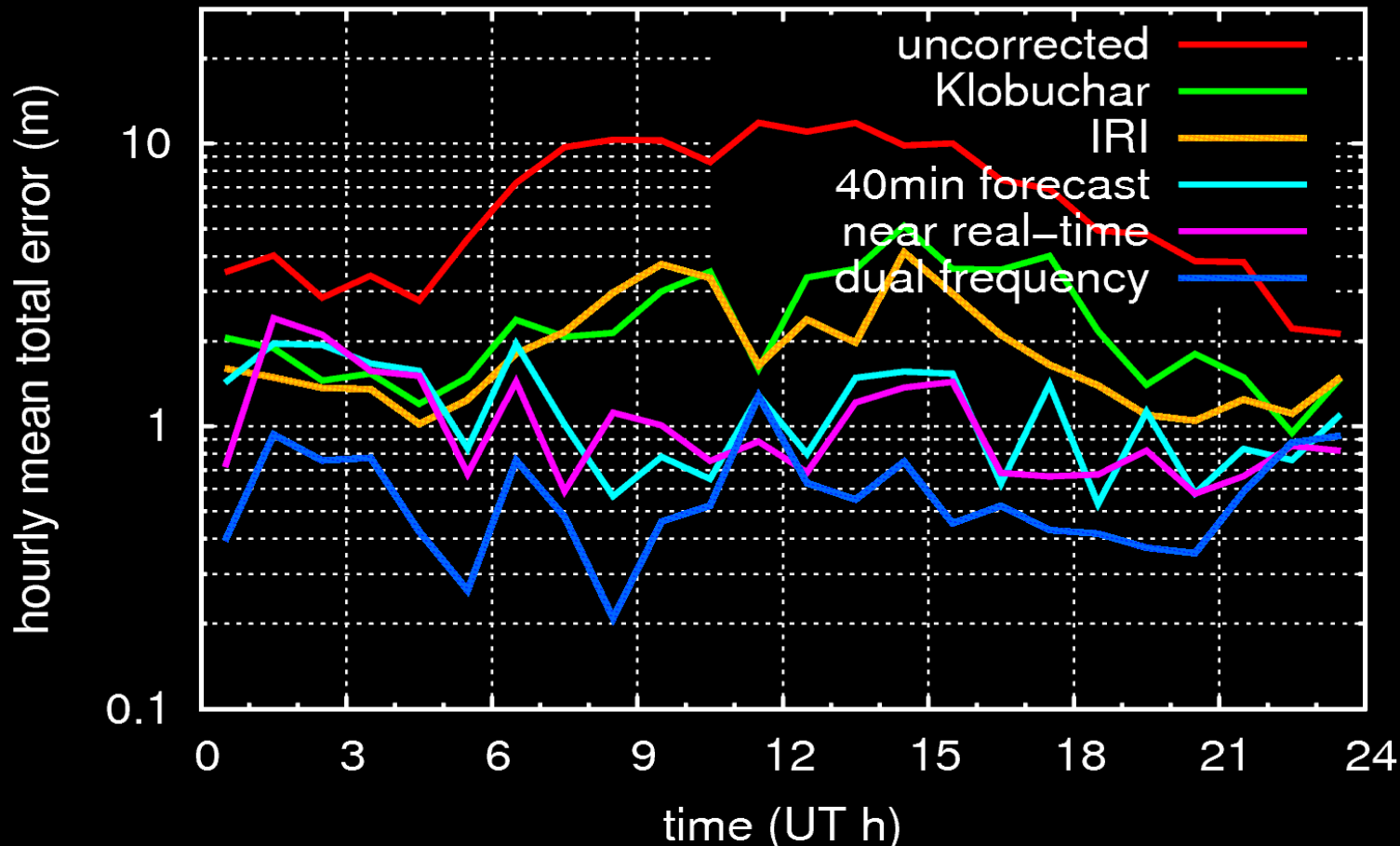
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Results : quiet day



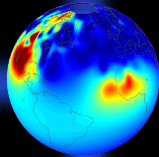
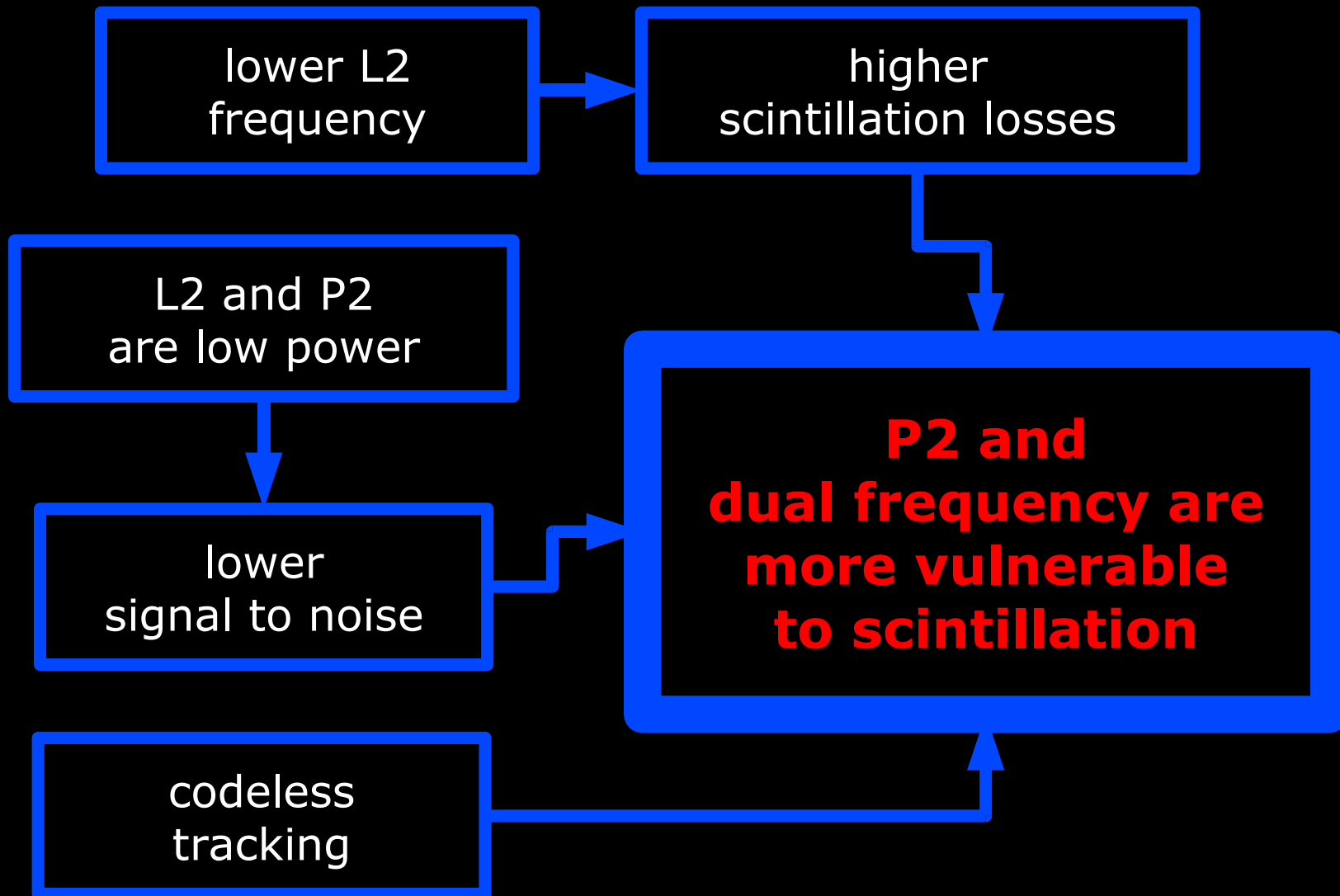
GOPE, 2002/10/13



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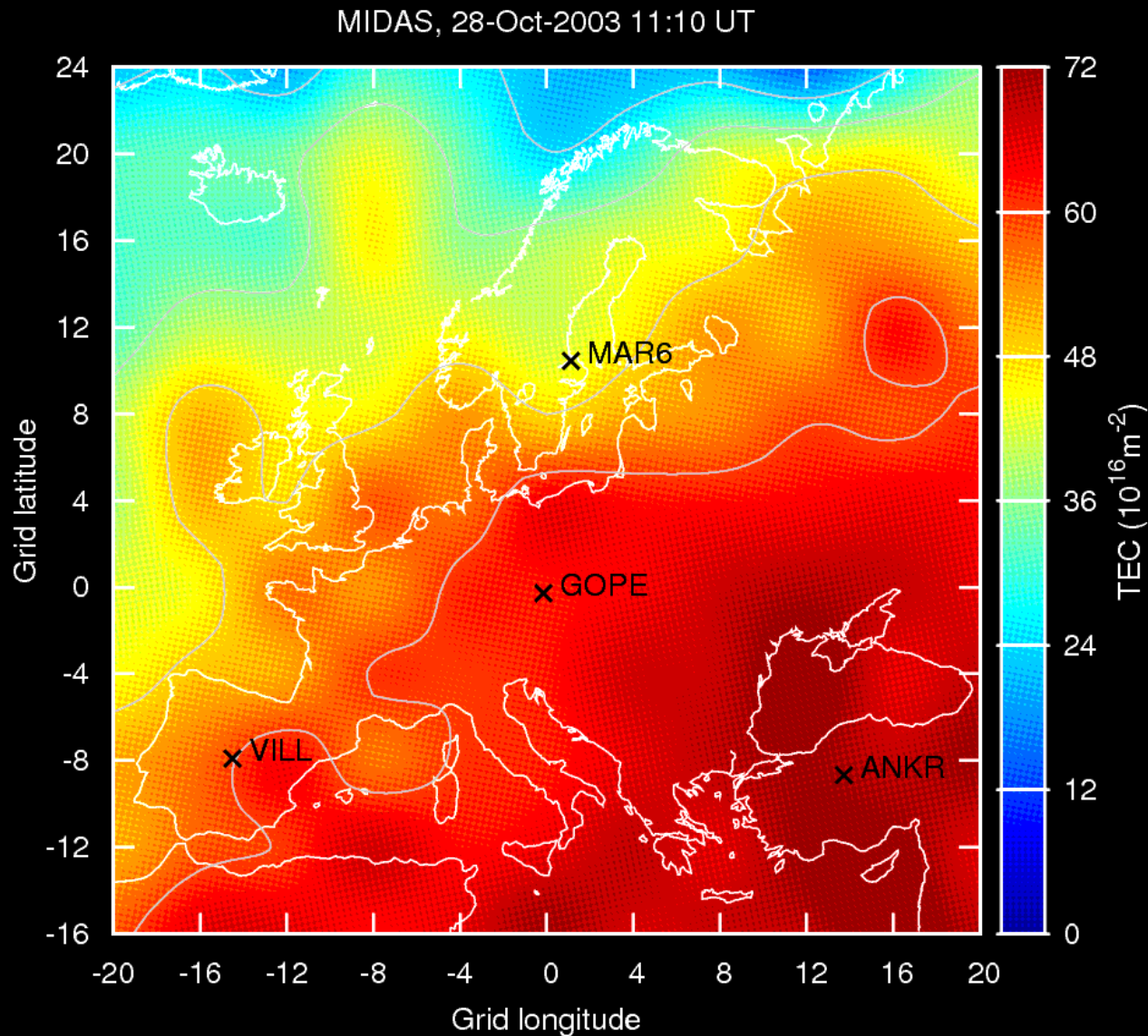
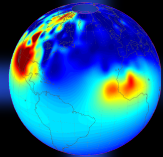
Scintillation



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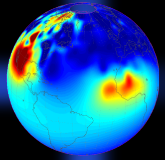
Results : storm



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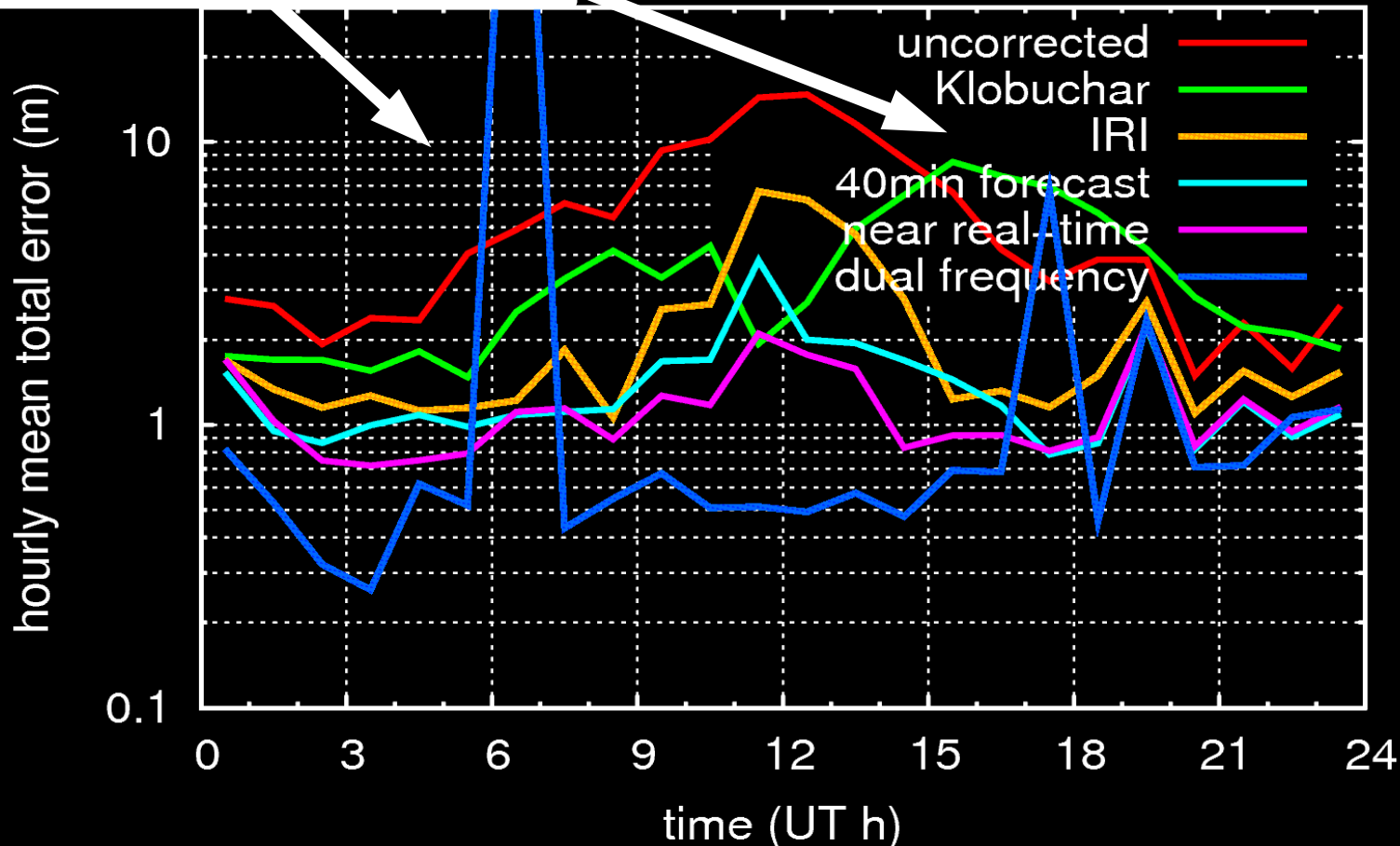


Results : storm



Losses of lock

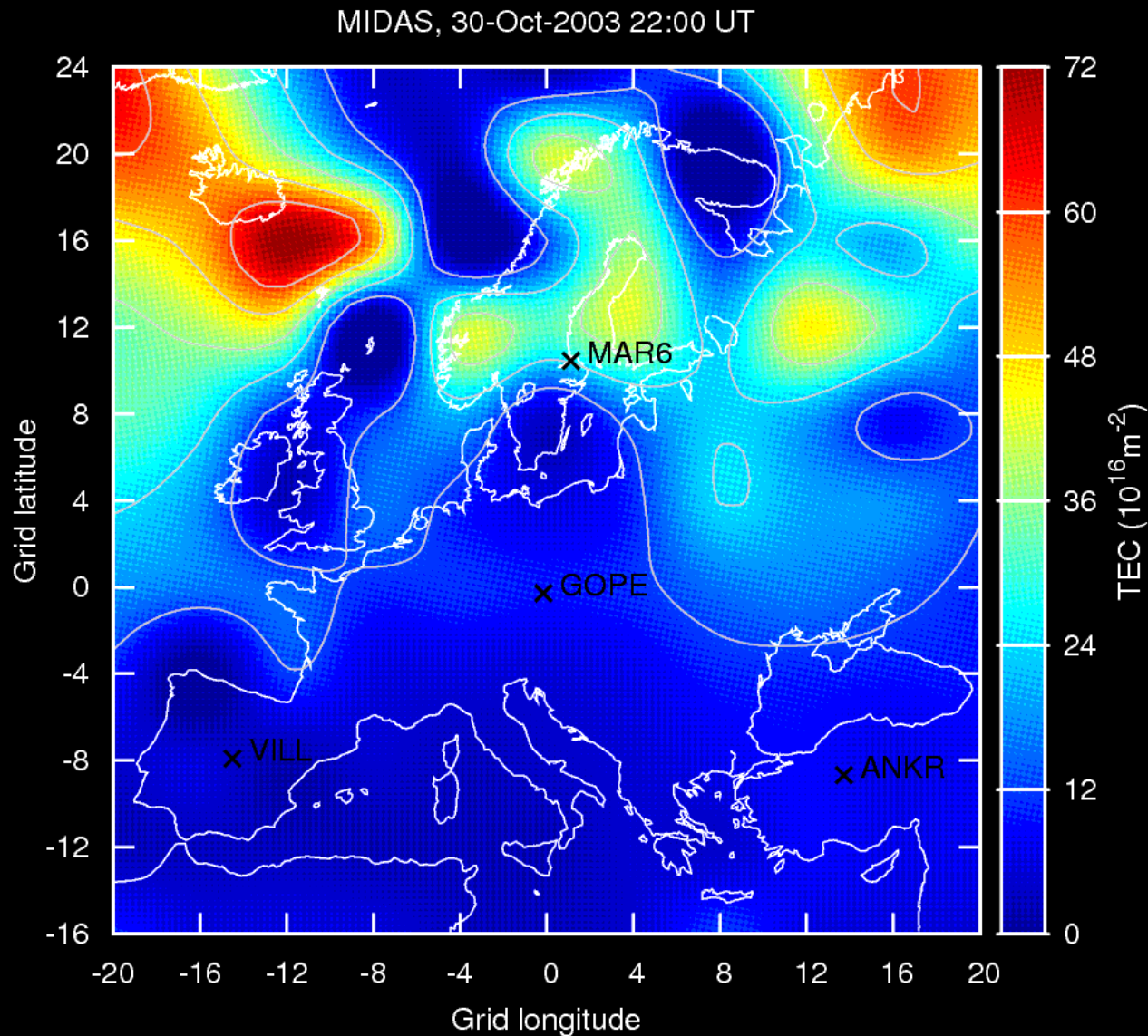
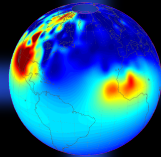
GOPE, 2003/10/28



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Results : storm



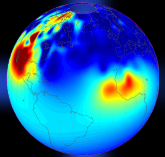
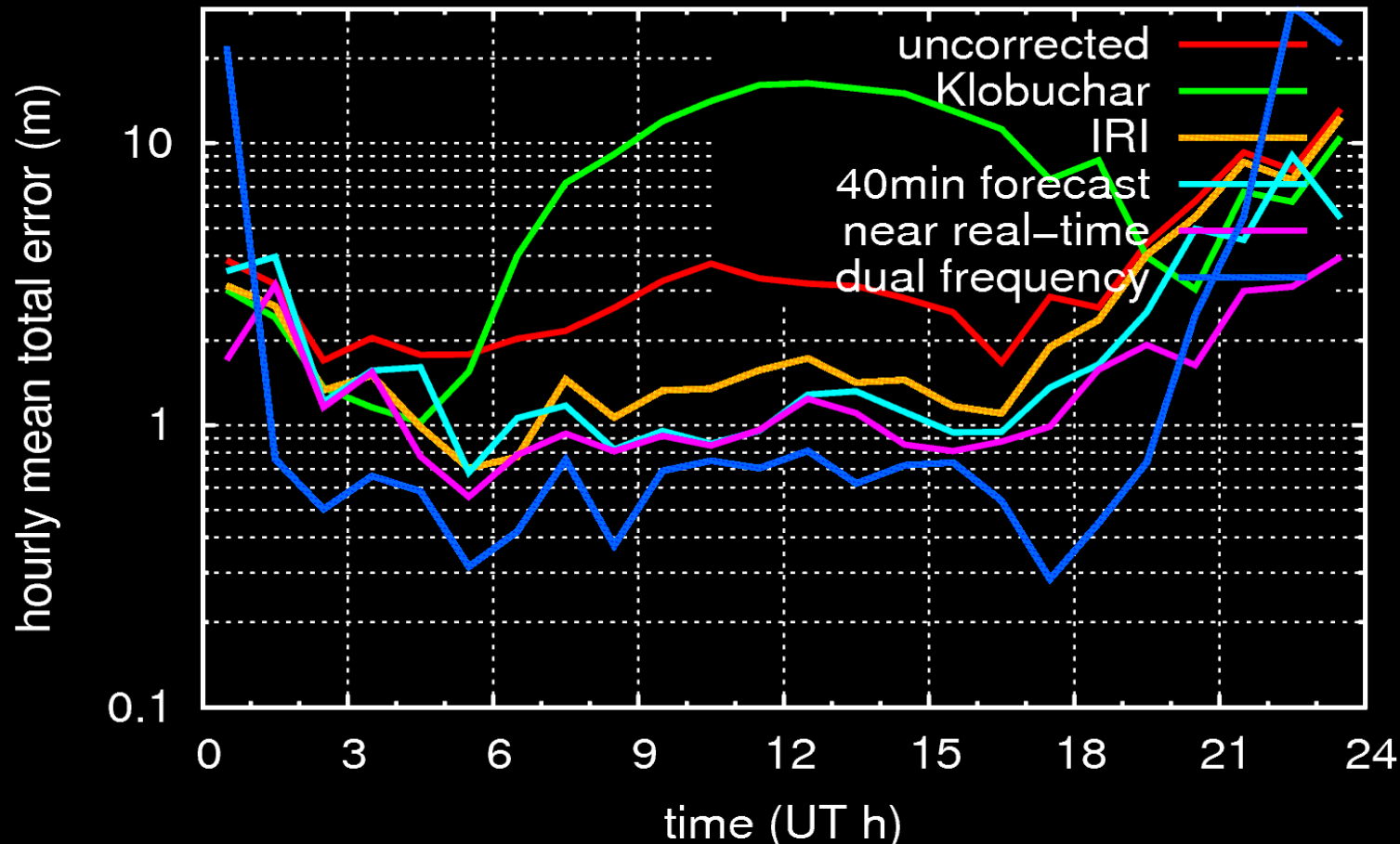
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Results : storm

Loss of lock

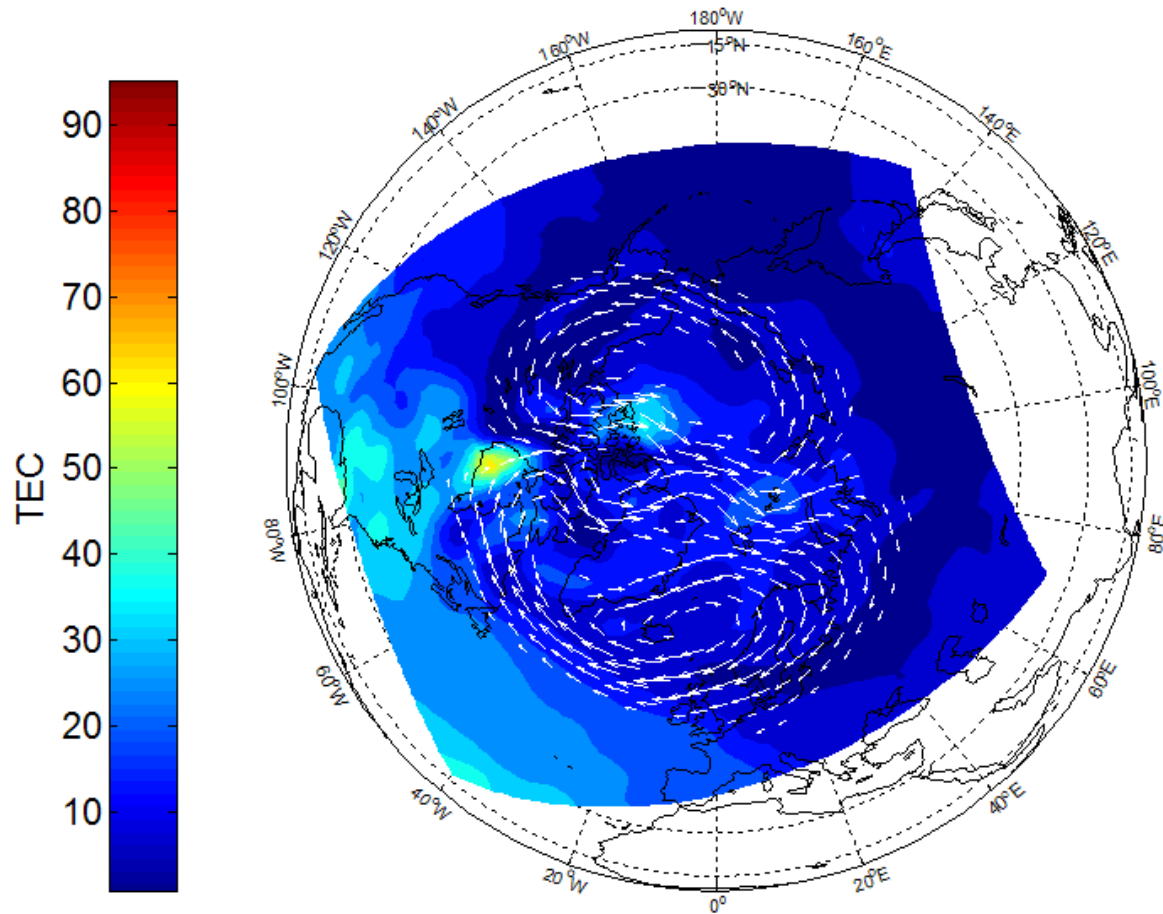
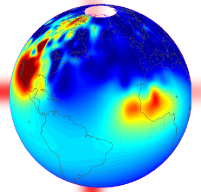
MAR6, 2003/10/30



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Results : storm

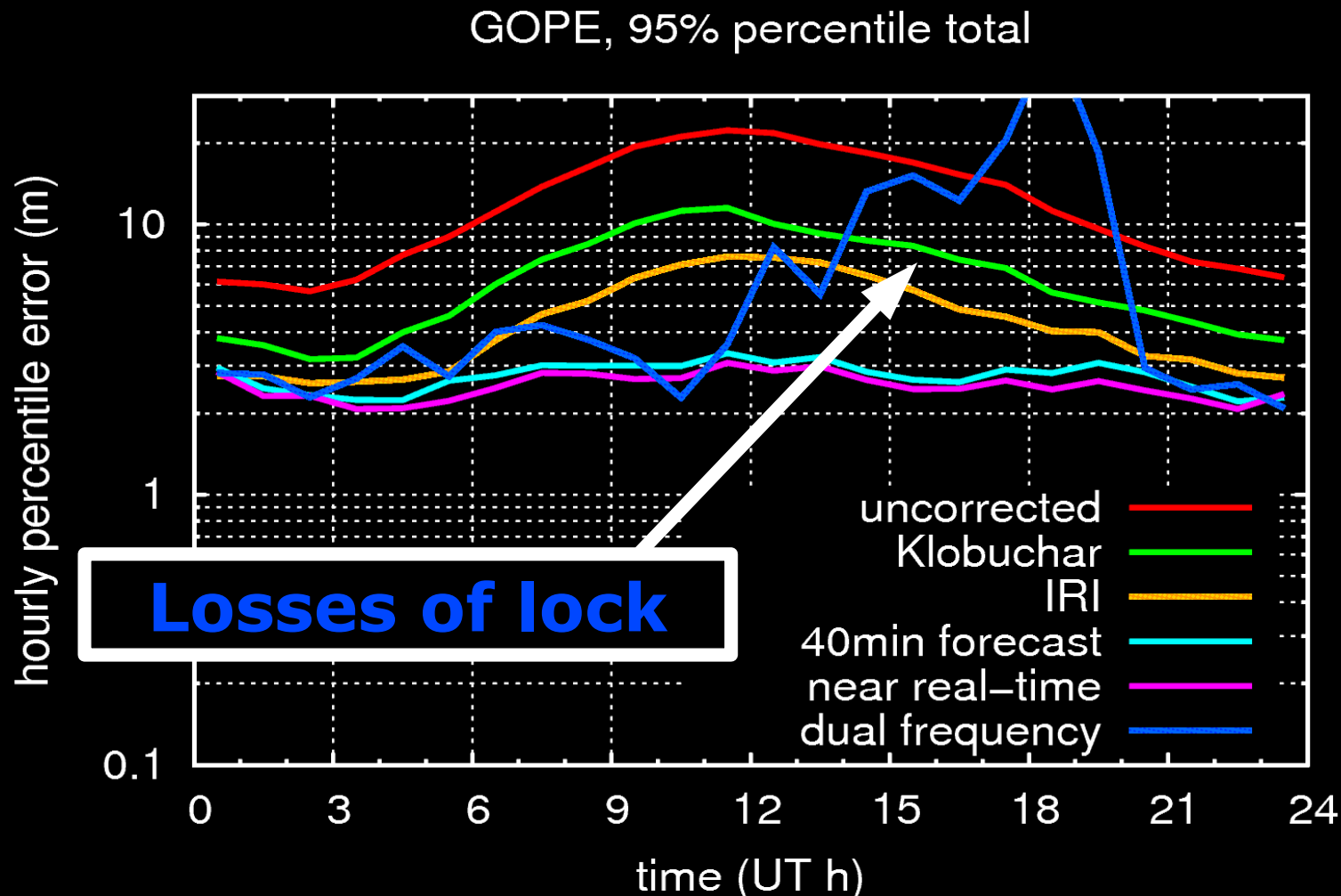
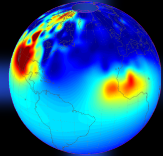


Total Electron content 30-Oct-2003 17:00:00UT

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Results : 95% confidence



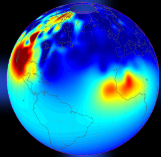
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Conclusion

Accurate and reliable predicted MIDAS corrections for real-time use are available :

<http://people.bath.ac.uk/da224/rti/>



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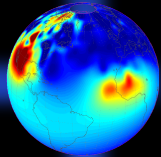
Any Questions ?



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<http://people.bath.ac.uk/da224/>

References

- Meggs RW, Mitchell CN (2006) A study into the errors in vertical total electron content mapping using gps data. Radio Science 41, DOI 10.1029/2005RS003308



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